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ABSTRACT

The purpose of this study was to confirm or deny Carry's findings in an earlier Aptitude Treatment Interaction (ATI) study by implementing his suggestions to: (1) revise instructional treatments, (2) improve the criterion measures, (3) use four predictor tests, (4) add time to criterion measure, and (5) use a theoretical model to identify relevant variables within each treatment. A pilot study of 77 students was used to decide that only a transfer test and time to criterion measure would be used. The final study involved 249 second-year algebra students in Waco, Texas, randomly assigned to either an analytical or a graphical treatment. Four classroom periods were used for the study. The treatments were found equally effective, with no interactions between any aptitude variable and either treatment. Item analysis produced no class of transfer test items exhibiting ATI. Thus, the study was inconsistent with Carry's, and ATI's are concluded to be more complex than originally believed. Recommendations for future ATI studies include use of many varied criterion measures, a study of differential aptitude variables, item analysis for consistency of transfer and retention tests before use of the scores, and development of homogeneous tests and longer instructional treatments. (JM)

Interaction Effects Between Selected Cognitive Abilities and Instructional Treatment In Algebra: An ATI Study

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In a review of literature related to the learning of mathematics, one finds numerous studies which have compared methods of teaching a selected mathematical concept to a group of individuals (Becker, 1970). Becker (1970) indicated that most of these studies are concerned with whether we can teach as well by method X as by method Y. At the same time Becker posed the following question: "For which students is a particular method of instruction most effective [p. 22]?"

In 1957, Cronbach, during his Presidential Address to the American Psychological Association, stated:

> Ultimately we should design treatments, not to fit the average person, but to fit groups of students with particular aptitude patterns. Conversely, we should seek out the aptitudes which correspond to (interact with) modifiable aspects of the treatment [p. 681].

An implication of this statement is that one should not ignore interactions between student's aptitudes and various instructional treatments, but *adapt* instructional treatments to student's aptitudes.

In 1965, Cronbach developed a theoretical framework to deal with the nature of differential aptitudes and differing instructional treatments. He called studies dealing with differential aptitudes and differing instructional treatments Aptitude Treatment Interaction studies, or more commonly called ATI studies.

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Nature of ATI

Cronbach (1957, 1967) has indicated that in order for instruction to be adapted to individual differences, three conditions must be met:

1. There must be different instructional methods.
2. The instructional methods must teach to the same objective or criterion.
3. There must exist one or more aptitude measures for which regressions of criterion scores upon the aptitudes exhibit a disordinal interaction.

There are essentially three different outcomes which can result when two differing instructional treatments are designed to interact with one or more aptitude variables (or predictors):

1. No interaction, where the regressior lines are parallel (See Figure 1).

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Insert Figure 1

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2. An ordinal interaction, where the regression lines do not cross within the range of scores of the aptitude variables (See Figure 2).

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Insert Figure 2

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3. A disordinal interaction, where the regression lines do cross within the range of scores of the aptitude variables. (See Figure 3).

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Insert Figure 3

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Note that in Figures 1, 2, and 3, one aptitude or predictor is regressed on some post test measure. If more than one aptitude measure is regressed on a post test measure, a regression plane or hyperplane, rather than a regression line, results.

It is cases 2 and 3 with which we are most interested. As Snow (1969) stated:

> If these lines intersect within the range of the aptitude variable, or if they can reasonably be extrapolated to intersect, or, even failing this, if the treatments differ substantially in cost, then the obtained interaction may justify a classification decision [p. 1].

Generally, an analysis of covariance test assumes parallel regression lines and tests for equal intercepts. However, if the regression lines are not parallel, then possibly an interaction exists, and it is this interaction one looks for in ATI studies. The investigator attempts to choose aptitude variables which he feels will interact with two or more differing instructional treatments.

Motivation for the study

The need for the study reported here resulted from an earlier ATI study conducted by Carry (1967). Carry compared graphical and analytical modes of Programmed Instructional (PI) materials in quadratic inequalities "to test hypothesis of interaction between two curriculum treatments and the aptitude variables General Reasoning and Visualization [p. 55]." The dependent variables used in the study were a learning test score and a transfer test score.

Carry's hypothesis was that there would be a disordinal interaction between treatments and predictors, and that general reasoning would predict

success in the analytical treatment and spatial visualization would predict success in the graphical treatment.

The results of the study indicated that there was no interaction when the learning test was used as a dependent measure, but there was a disordinal interaction on the transfer test at the .01 level of significance. Hence, an ATI did exist when the transfer test was used as the dependent or criterion measure. However, the interaction was in the *opposite* direction of prediction, that is general reasoning predicted success in the graphical treatment and spatial visualization predicted success in the analytical treatment. Carry (1967) indicated the following with respect to the findings:

> ...there are aspects of this finding which prevent an unqualified claim of success in establishing an interaction. First the observed interaction is not consistent with theoretical prediction.... Second, the low alpha reliability estimate [.14 on the transfer test] casts doubt on the accuracy of the regression coefficients. These qualifications do not suggest that the treatments failed to interact with the ability measures in predicting achievement, but rather that the evidence is inconclusive [p. 44].

The comments by Carry provided the motivation to conduct a follow up study, which will now be discussed. The primary purpose of this study was to implement suggestions made by Carry in his study by:

1. Revising the instructional treatments.
2. Improving the criterion measures.
3. Choosing four predictor tests, two each for spatial visualization and general reasoning.
4. Adding a time to criterion measure.
5. Using a theoretical model developed by Melton (1967) to attempt to identify relevant variables within each treatment.

The treatments used by Carry were revised, rewritten and extended. One treatment, the analytical treatment, was designed to utilize the multiplicative property of signed numbers. It was called Treatment A. The second treatment, the graphical treatment, or Treatment G, was designed for maximum utilization of graphs as a vehicle for mathematical learning. PI materials were used solely to control for any teacher bias that might have existed in presenting the content.

While a combination of analytical and graphical treatment components might possibly produce a stronger learning effect for all students, the separation into two distinct treatments is a useful research strategy which could offer more clarity in understanding the separate functions of the treatments and abilities involved. A combined treatment might mask or conceal the functioning of aptitudes which may be interacting with treatment effects. As Cronbach (1957) has advocated, unless one treatment is clearly the best for all individuals, then the treatments should be differentiated in such a way as to maximize their interaction with the aptitude variables. If this is accomplished and interactions do exist, then learning is maximized.

Also, new learning and transfer tests were developed, the learning test containing fifteen items, and the transfer test containing twenty items. Both Carry (1967) and Cronbach and Snow (1969) suggested at least two predictor tests be used for each aptitude selected. Hence two tests for the spatial visualization aptitude and two tests for the general reasoning aptitude were selected. The tests utilized were obtained from the *Kit of Reference Tests for Cognitive Factors* (French, Ekstrom and Price, 1963)

and from Guilford (1952). The titles of the tests are listed in Table 4, along with the descriptive statistics of the pre and post tests.

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Insert Table 4

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A pilot study was conducted with 77 students, and as a result of the data obtained from the study, it was decided to include only a transfer test and a time to criterion measure in the final study.

The subjects for the final study were 249 second year algebra students selected from a high school in Waco, Texas. The students were randomly assigned to either Treatment A or Treatment G. Four classroom periods were required to conduct the study:

1. Day 1 - Administration of the pretests
2. Days 2 and 3 - Reading of the PI booklet
3. Day 4 - Administration of the transfer test

The general hypotheses was to attempt to confirm or deny Carry's findings, that is to determine whether an interaction existed between the instructional treatments and the aptitude variables, spatial visualization and general reasoning. The list of specific hypotheses is presented in Table 5.

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Insert Table 5

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Results

Generally the results were as follows:

1. The treatments were equally effective. Table 6 depicts the statistics of this result.

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Insert Table 6

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2. The reliability coefficients of the transfer test measure were somewhat improved over the Carry study (.66 and .65 respectively), but they still reflect only a moderate degree of internal consistency.

3. Whether the aptitude variables were considered individually or collectively, and regressed on either post test, there were *no* interactions found between any aptitude variable and either treatment. That is, the regression lines were parallel and nearly superimposed on each other. Tables 7, 8, and 9 depict the pertinent statistics of these results.

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Insert Tables 7, 8, 9

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An analysis of each transfer test item individually also resulted in only two out of 80 possible ATI's. This is only a chance occurance. Table 10 includes these ATI tests.

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Insert Table 10

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In summary, no evidence was exhibited supporting the hypotheses that the two instructional treatments interacted with the aptitude variables on either post test measure. Further, an item by item analysis produced no consistent

class of transfer test items exhibiting ATI. A comparison of two common items in this study and the Carry study also yielded inconsistent results. Table 11 includes these results. These results seem to indicate that ATI's are much more complicated than originally anticipated and that studies do not necessarily yield consistent results.

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Insert Table 11

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Recommendations

Looking at these results and the procedures used in this study, when further investigations of ATI's are conducted, several modifications are suggested.

1. The investigator recommends that designs of future ATI studies include as many different criterion measures as possible (e.g. learning tests, retention tests, time to criterion measures, etc.). Unless some a priori information is available to suggest that a particular criterion measure not be used, the current state of the theory of ATI is not well enough developed to determine the specific dependent variables that should or should not be selected.

2. A careful study and investigation of possible differential aptitude variables should be conducted. For example, in previous studies, general intelligence measures, such as IQ tests, were not particularly promising differential aptitude variables since they did not have a differential effect on the treatments.

3. Measures of transfer test scores or retention test scores should be utilized only after an item by item analysis is conducted. If consistent results are obtained for each item, then the total test score could be considered. If inconsistent results are obtained on a item by item analysis, then caution should be taken when interpreting results using the total test score as the criterion.

4. An attempt should be made to develop homogeneous tests so that an item by item analysis would yield more consistent results, and the internal consistency reliability coefficients of the tests as a whole would be higher than those obtained in this experiment.

5. Longer instructional treatments should be developed. It is the investigator's belief that the length of the instructional treatment is probably one of the most important dimensions to consider when designing an ATI study. Cronbach and Snow (1969) make reference to a ''learning to learn phenomenon'' which they say is

> the tendency of persons to do considerably better on problems or learning tasks after they have had experience with many problems of the same kind. The learning ability displayed on the first few problems of such a series may not be the most significant indication of thy person's ability to perform in an instructional situation or elsewhere where learning will be continued over a long time [p. 42].

Hence, it is possible that a learning to learn phenomenon might have been a relevant dimension to consider in this study. Therefore, in future ATI experiments, studies conducted over a long period of time are likely to be of more practical use.

While the results of this experiment are not particularly promising, the investigator does not intend to convey the interpretation that additional ATI studies should not be conducted. Hopefully, further ATI

experiments will be conducted in various content areas, so that eventually the ATI hypothesis can be either denied or confirmed.

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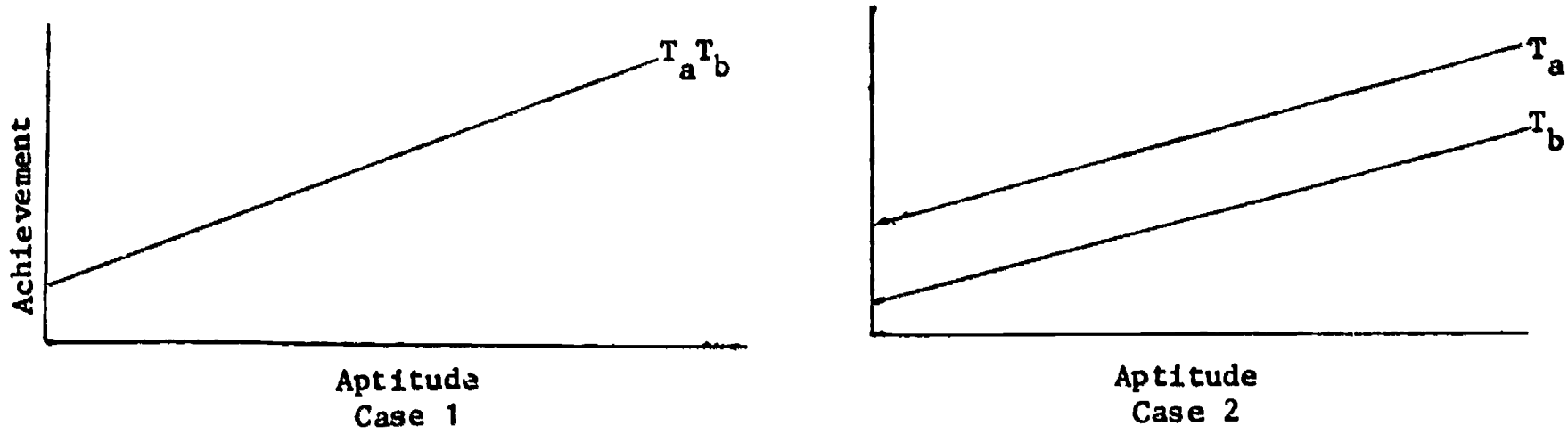
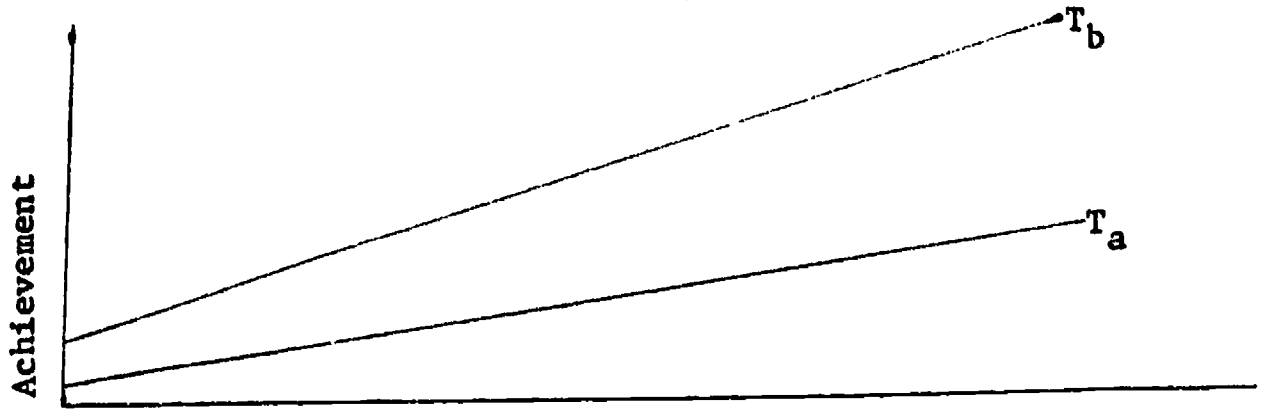
Figure 1



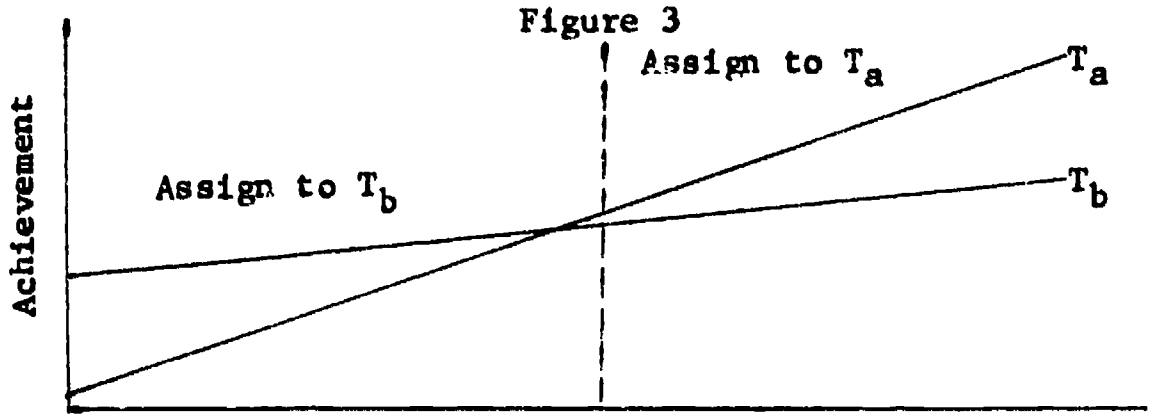
Regression Lines for Two Treatments-
No Interaction

Figure 2



Regression Lines for Two Treatments-
Ordinal Interaction.

Figure 3



Regression Lines for Two Treatments-
Disordinal Interaction.

Table 4

MEANS AND STANDARD DEVIATIONS
OF PRETESTS AND POSTTESTS

Test	Maximum Score Possible	Treatment Group			
		Analytical[a]		Graphical[a]	
		Mean	S.D.	Mean	S.D.
Spatial Visualization II	40	13.09	6.58	13.64	7.16
Paper Folding	20	10.44	3.57	10.27	4.20
Necessary Arithmetic Operations	30	15.25	4.75	15.25	4.72
Mathematics Aptitude Test	10	3.40	2.31	3.33	2.01
Transfer Test	20	9.07	3.14	8.60	3.27
Time to Criterion	--	62.98	17.02	61.95	18.46

[a]N = 124 and N = 125 for the A and G treatments, respectively, except for the time to criterion measure where N = 100 and N = 110, respectively.

Table 5. Specific Hypothesis tested

When scores on a transfer test, following programmed instruction on a unit in quadratic inequalities using either a graphical treatment or an analytical treatment, are regressed on measures of the aptitude variables, spatial visualization and general reasoning, then:

1. The mean scores in each treatment will not be significantly different from each other.

2. The regression hyperplanes across treatments will not be parallel.

3. The regression weights of the aptitude measures for spatial visualization will be significantly different from zero only in the analytical group.

4. The regression weights of the aptitude measures for general reasoning will be significantly different from zero only in the graphical group.

When scores on a time to criterion measure, following programmed instruction on a unit in quadratic inequalities using either a graphical treatment or an analytical treatment, are regressed on measures of the aptitude variables, spatial visualization and general reasoning, then:

5. The mean scores for the time to criterion in each treatment will not be significantly different from each other.

6. The regression hyperplanes across treatments will not be parallel.

7. The regression weights of the aptitude measures for spatial visualization will be significantly different from zero only in the graphical group.

8. The regression weights of the aptitude measures for general reasoning will be significantly different from zero only in the analytical group.

Table 6a

TEST FOR EQUAL TREATMENT
MEANS-TRANSFER TEST

Source	SS	df	MS	F	p
Treatment Means	13.9022	1	13.9022	1.4	.25
Error	2564.3540	247	10.3820		

Table 6b

TEST FOR EQUAL TREATMENT
MEANS--TIME TO CRITERION

Source	SS	df	MS	F	p
Treatment Means	55.0816	1	55.0816	.17	.68
Error	66496.7264	208	319.6958		

Table 7

WITHIN GROUP CORRELATION COEFFICIENTS
ANALYTICAL GROUP

Test		Correlations					
		1	2	3	4	5	6
1	Sp. Vz. II		.51*	.22*	.24*	-.05	.13
2	Paper Folding			.29*	.28*	-.02	.09
3	Nec. Arith. Opns.				.48*	-.19*	.18*
4	Math. Apt. Test					-.06	.31*
5	Time to Criterion						-.07
6	Transfer Test						

WITHIN GROUP CORRELATION COEFFICIENTS
GRAPHICAL GROUP

Test		Correlations					
		1	2	3	4	5	6
1	Sp. Vz. II		.57*	.15	.24*	-.07	.11
2	Paper Folding			.30*	.37*	-.05	.22*
3	Nec. Arith. Opns.				.47*	-.08	.29*
4	Math. Apt. Test					-.16	.33*
5	Time to Criterion						-.01
6	Transfer Test						

*Denotes a significant correlation coefficient at the .05 level.

Table 8

ATI TEST FOR EQUALITY OF THE VECTOR OF REGRESSION COEFFICIENTS FOR FOUR PREDICTORS- TRANSFER TEST MEASURE

Source	SS	df	MS	F	p
Heterogeneity of Regression	21.9945	4	5.4986	.58	.67
Error	2247.8307	239	9.4051		

REGRESSION OF TRANSFER TEST ON EACH MARKET TEST INDIVIDUALLY

Marker Test	Exp. Grp.	Inter-cept	Raw Wt.	Std. Wt.	Mult. R	F[a]	p
Sp. Vz. II	A	8.2341	1.0640	.1343	.1343	2.24	.14
	G	7.8880	0.521	.1140	.1140	1.62	.20
Paper Folding	A	8.2190	.0817	.0929	.0929	1.06	.30
	G	6.8152	.1737	.2229	.2229	6.43	.01
Nec. Arith. Operations	A	7.2804	.1175	.1779	.1779	3.97	.05
	G	5.5229	.2018	.2910	.2910	11.38	.001
Mathematics Achievement	A	7.6166	.4278	.3149	.3149	13.43	.0004
	G	6.7989	.5409	.3313	.3313	15.17	.0002

[a]Degrees of freedom for analytical group is (1,122) and degrees of freedom for graphical group is (1,123).

Table 9

ATI TEST FOR EQUALITY OF THE VECTOR OF REGRESSION COEFFICIENTS FOR FOUR PREDICTORS- TIME TO CRITERION MEASURE

Source	SS	df	MS	F	p
Heterogeneity of Regression	736.4153	4	184.1038	.57	.68
Error	64188.7159	200	320.9436		

REGRESSION OF TIME TO CRITERION ON EACH MARKET TEST INDIVIDUALLY

Marker Test	Exp. Grp.	Inter-cept	Raw Wt.	Std. Wt.	Mult. R	F[a]	p
Sp. Vz. II	A	64.315	-.1398	-.0511	.0511	.25	.61
	G	64.689	-.1977	-.0749	.0749	.61	.43
Paper Folding	A	64.403	-.1845	-.0375	.0375	.14	.71
	G	64.015	-.1986	-.0460	.0460	.23	.63
Nec. Arith Operations	A	71.997	-.6110	-.1617	.1617	2.63	.10
	G	66.965	-.3207	-.0784	.0784	.69	.41
Mathematics Achievement	A	64.812	-.6687	-.0843	.0843	.70	.41
	G	67.562	-1.6010	-.1605	.1605	2.99	.08

[a]Degrees of freedom for analytical groups is (1,98) and degrees of freedom for graphical group is (1,108).

Table 10

REGRESSION OF EACH TRANSFER TEST ITEM
ON ALL PREDICTORS-ATI TESTS INCLUDED

Item	Exp. Grp.	Spatial Vz. II			Paper Folding			Nec. Arith. Opns.			Math. Achievement		
		Std. Wts.	F	ATI F	Std. Wts.	F	ATI F	Std. Wts.	F	ATI F	Std. Wts.	F	ATI F
1	A	.13	2.08	4.16*	.21	5.41*	1.88	.09	1.14	.15	.17	3.80*	.09
	G	-.13	2.11		.04	.20		.13	2.33		.17	3.76*	
2	A	-.03	.15	.30	.09	.92	.55	.12	1.80	.24	.22	6.15**	.68
	G	-.08	.99		-.02	.04		.03	.09		.05	.25	
3	A	-.03	.11	.22	.03	.13	.24	-.10	1.30	.63	.04	.16	.60
	G	.03	.11		.09	1.09		.01	.01		.11	1.50	
4	A	.20	5.05*	2.75	.15	2.80	1.25	.28	10.29**	1.60	.23	6.85**	2.53
	G	.01	.01		.02	.03		.11	1.50		.01	.01	
5	A	.11	1.52	.60	.18	4.39*	.98	.14	2.40	.78	.18	4.01*	.30
	G	.01	.01		.06	.43		.01	.02		.07	.63	
6	A	-.04	.16	.41*	-.03	.08	.59	-.11	1.49	8.69**	-.02	.05	2.02
	G	.05	.25		.07	.68		.25	8.20**		.14	2.60	
7	A	.03	.07	.01	-.01	.00	.12	-.04	.20	1.70	.08	.83	.80
	G	.03	.12		.04	.22		.12	1.97		.04	.23	
8	A	.07	.64	.16	.07	.59	1.30	.14	2.57	1.26	.12	1.83	1.42
	G	.02	.07		.24	7.51**		.28	10.70**		.25	7.97**	
9	A	.13	2.16	.02	.02	.06	1.60	.19	4.70*	.18	.29	11.30**	.04
	G	.16	3.34		.20	5.27*		.24	7.90**		.27	10.20**	
10	A	.17	3.61*	.05	.14	2.46	.09	.06	.46	.87	.26	8.70**	.03
	G	.21	5.83**		.20	5.38*		.18	4.01*		.20	5.04*	

*Significant at the .05 level. **Significant at the .01 level.
Degrees of freedom for Regression F, group A is 1,122; for group G is 1,123.
Degrees of freedom for Interaction F is 1,245.

Table 10 (cont'd)

REGRESSION OF EACH TRANSFER TEST ITEM
ON ALL PREDICTORS-ATI TESTS INCLUDED

Item	Exp. Grp.	Spatial Vz. II			Paper Folding			Nec. Arith. Opns.			Math. Achievement		
		Std. Wts.	F	ATI F	Std. Wts.	F	ATI F	Std. Wts.	F	ATI F	Std. Wts.	F	ATI F
11	A	-.06	.50	1.17	.06	.44	.35	.02	.05	.17	-.09	.89	1.22
	G	.07	.68		-.01	.01		-.03	.12		.06	.41	
12	A	.04	.15	.11	.02	.02	.01	-.01	.03	.77	.07	.61	.88
	G	-.01	.11		.03	.11		.09	1.09		.17	3.48	
13	A	.06	.49	.80	-.05	.27	2.53	.04	.20	.00	.16	3.18	.26
	G	.19	4.42*		.16	3.42		.03	.15		.08	.72	
14	A	.14	2.40	.53	.02	.07	1.11	.04	.24	2.42	.13	2.15	.81
	G	.06	.40		.18	4.03*		.24	7.77*		.22	6.55*	
15	A	.06	.48	.27	-.02	.04	.45	.06	.47	.16	.10	1.21	1.02
	G	.14	2.49		.07	.64		.12	1.67		.21	5.65**	
16	A	.08	.82	.02	-.01	.01	.15	.12	1.93	.98	.15	3.00	.45
	G	.07	.59		.04	.25		.00	.00		.05	.36	
17	A	-.16	3.50	1.06	-.11	1.41	1.57	.03	.09	.34	-.04	.17	1.42
	G	-.05	.30		.04	.28		.10	1.35		.11	1.53	
18	A	.12	1.86	.77	-.07	.55	.20	.05	.34	.02	.06	.48	2.48
	G	-.01	.01		-.10	1.38		.05	.34		.19	4.79*	
19	A	-.09	.99	.40	-.08	.82	1.80	-.01	.00	.21	.06	.46	.44
	G	-.01	.02		.09	1.01		.06	.42		-.03	.08	
20	A	.14	2.40	1.68	.12	1.77	.74	.20	5.23*	1.76	.19	4.60*	1.70
	G	-.03	.08		.02	.03		.03	.09		.01	.00	

*Significant at the .05 level. **Significant at the .01 level.
Degrees of freedom for Regression F, group A is 1,122; for group G is 1,123.
Degrees of freedom for Interaction F is 1,245.

Table 11

COMPARISON OF RAW WEIGHTS FOR TWO ITEMS
USED IN THIS STUDY AND IN THE CARRY STUDY

Item	Exp. Grp.	Paper Folding		Nec. Arith. Opns.	
		Webb	Carry	Webb	Carry
1	A	-.001	.016	.013	.010
	G	.005	.000	.000	.035*
2	A	-.003	.037*	.006	-.002
	G	.008	.024	.012	.048**

*Significant at the .05 level.
**Significant at the .01 level.